Review

Seven cognitive concepts for successful eco-design

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Abstract

This article is a review of research on encouraging pro-environmental behavior in a variety of fields and applies the results to create recommendations for eco-design. Environmental psychology, behavioral psychology, consumerism, business, environmental political science, and additional social science research were used to define cognitive concepts that led to the purchase and use of eco-products. The concepts and basic explanations are: (1) responsibility, a sense of personal control over actions and outcomes; (2) complex decision-making skills, mental tools that structure complex decisions; (3) decision heuristics, mental shortcuts that simplify judgments and decisions; (4) the altruism-sacrifice link, an assumption that doing good requires personal sacrifice; (5) trust, the degree to which a person believes the information they are given; (6) cognitive dissonance/guilt, the mental processes that may occur when a mismatch between intention and action is identified; and (7) motivation, intrinsic and extrinsic satisfaction that drives behavior. Eco-product examples are provided to highlight the role of the cognitive concepts design. Design recommendations and relevant design methods are discussed. The recommendations require coordination between designers, manufacturers, marketers, and government policy-makers to achieve positive changes in individuals’ behavior.

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1. Introduction

For the past forty years, researchers, mainly in the social sciences, have studied how to encourage the adoption of recycling programs, water conservation strategies, and other individual pro-environmental efforts. This article presents a literature review as it relates to the design of eco-products and technologies and first defines the approach and method of the review. Then it gives an overview of relevant terms such as “attitude” and “pro-environmental behavior” (PEB). The rest of the article is devoted to exploring the seven cognitive concepts, interspersed with recommendations for designers and relevant emerging design methods.

Consider a continuum of eco-product success, shown in Fig. 1, as defined by customer attitude: some individuals actively seek out eco-products to buy and use (strong purchase criteria); some do not seek them out, but a product’s reduced environmental impact will create a preference for the product over an otherwise identical alternative (weak purchase criteria); some individuals are neutral to eco-products (neutral); and, unfortunately, some individuals find consideration of the environment in a product’s design to be a drawback (negative purchase criteria)—for reasons to be explored later. Metaphorically speaking, this article aims to create “positive movement” along this continuum by inspiring engineers and designers to design eco-products that encourage such movement. Moving customers along this continuum towards the active pursuit of eco-products is advantageous to the environment and the company producing the product, and to policy-makers, as it may reduce the expense of time and money required to institute a new product-related policy. Increased demand, reduced environmental impacts, and easier policy implementation will spur development of eco-products.

There are many resources on the technological side of eco-design: For integrated sustainable life cycle design see (Ramani et al., 2010); for taxonomy of sustainable design tools and guidance on selecting the tools see (Boeva and Pérez-Belis, 2012); for initiatives and efforts taken by different stakeholders to promote sustainable production and consumption see (Barber, 2007); for a special issue on how to achieve eco-design see (Huisingsh, 2006; Karlsson and Luttropp, 2006).
1.1. Approach and method

The discussion here is centered on the design of mass-market eco-products. The working definition of eco-product used throughout this article is: a product that is intentionally and methodically designed to decrease environmental impact versus the status quo, be that a competing product or an otherwise-defined baseline, using a scientifically-based environmental impact assessment tool of the designer's choosing.

To narrow the discussion, this article assumes that individuals are concerned about the negative impact they have on the environment, rather than addressing the equally-important issues of public awareness and environmental education. Guber provides an excellent analysis of public opinion concerning the environment and documents that the level of public concern for the environment varies widely by date and by survey framing (Guber, 2003).

This article represents a synthesis of findings from literature in the fields of environmental and behavioral psychology, consumerism, business and marketing, environmental political science, and design for sustainable behavior. It focuses on research conducted in the United States and Europe. Summary and review articles are referenced wherever possible to aid the reader in furthering their education. A brief introduction and relevant literature reviews for these fields are presented below.

Environmental psychology provides insight into a person's relationship with their physical environment, and it increasingly expands into public policy, concern with technology, and connection with other disciplines in recent years, as indicated by Gifford (2007). For a review of environmental psychology as a discipline, see (Gifford, 2007) and the corresponding special issue of the Journal of Social Science, and a special issue of American Psychologist (McKenzie-Mohr, 2000; Winter, 2000). Gifford (2007) outlines emerging themes, growth, and challenges in environmental psychology regarding contributing to sustainable development. McKenzie-Mohr (2000) proposes a four-step framework to support fostering sustainable behavior in a community, and identifies seven cognitive concepts/"tools" as possible solutions to fulfill this objective: commitment, social norms, social diffusion, prompts, communication, incentives, and convenience. Winter (2000) discusses neoanalytical, behavioral, social, and cognitive approaches and outlines how to address the psychology of sustainability from these perspectives. For a review of the psychology of forming preferences, see (Slovic, 1995), which also demonstrates that different elicitation procedures produce different preferences.

Behavioral psychologists offer insight into the psychological precursors to performing PEB. For a review of studies, see (Stern, 2000) whose Value-Belief-Norm theory provides a sympathetic conclusion to the discussion below: the causes for PEB are not always clear and a combination of corrective approaches works best when attempting to change behavior. Some researchers have found that environmental attitude alone is not a good predictor of PEB (McKenzie-Mohr, 2000; Roberts, 1996; Vining et al., 2002). McKenzie-Mohr (2000) discusses factors that affect behavior: commitment, social norms, social diffusion, prompts, communication, incentives, and convenience. Researchers have reported a varying degree of connection between intentions formed directly before performing a PEB and the behavior that follows (Koehn, 2006). As tested in the Comprehensive Action Determination Model (Klöckner and Blöbaum, 2010), PEB is affected not only by intention, but also by habits, social and personal norms, and subjective and objective situational constraints.

Business research requires a balance between profit growth and pro-environmental implementations and thus poses new challenges for sustainability. Green marketing, as a sub-discipline of business research, is the study of positioning eco-products in the market for profitability. For a review of green marketing, see (Peattie and Charteris, 2008), and note the special issue on sustainability in the Journal of the Academy of Marketing Science (JAMS) (Hult, 2011). Peattie and Charteris (2008) discuss the influence of "green challenge" on current marketing practice, and the marketing strategies to promote pro-environmental behavior, as well as practical challenges. The special issue in JAMS consists of a set of 10 articles providing information for researchers and related stakeholders on sustainability and marketing (Hult, 2011). Connelly et al. (2011) developed a "theoretical toolbox" using nine organizational theories (transaction cost economics, agency theory, institutional theory, organizational ecology, resource dependence theory, the resource-based view of the firm, upper echelons theory, social network theory, and signaling theory) and discussed their implications on sustainability. Peloza and Shang (2011) addressed sustainability from the perspective of corporate social responsibility (CSR) and stakeholders. They suggested that different types of CSR activities have different effects on stakeholder perceptions of value and even stakeholder behavior. Their review of previous research identifies three broad categories of CSR: philanthropy, business practices, and product-related.

Consumerism studies people as the purchasers and consumers of goods as a large-scale phenomenon, accounting for a large portion of environmental issues. Environmental political science studies how to affect or influence large-scale environmental changes through governmental (or other organizational) efforts, for example discouraging some behavior (e.g., littering) and encouraging others (e.g., purchase of alternate fuel vehicles). For a review of motivating consumer behavioral change and environmental policy implications (focused on the United Kingdom) see (Jackson, 2005). It reviews models of consumer behavior, motivating behavioral change, and environmental policy implications. Dolan et al. (2012) identify nine factors influencing human behavior and its change: messenger, incentives, norms, defaults, salience, priming, affect, commitment, and ego (MINDSPACE). They discuss how to apply these factors to policy making.

Design for Sustainable Behavior uses a multidisciplinary perspective to proactively improve sustainability through design. Boks (2006) identifies socio-psychological factors that play a role in the successful implementation of eco-design, such as the development of company-specific eco-design tools and the creation of guidelines and roadmaps. Pettersen and Boks (2008) mention four main strategies to promote behavior change: political measures, education, community-based social marketing, and technology. They emphasize user-centered strategies for eco-design, such as eco-feedback, and emotional attachment. Lockton et al. (2010a) present the Design with Intent Method for influencing behavior through six approaches: architectural, error-proofing, persuasive, visual, cognitive, and security.

Literature Review and Synthesis Method. In order to identify relevant literature from seven-plus fields of rich academic research our approach focuses on literature relevant to facilitating successful eco-design to use social science research to help engineers design...
eco-products with increased market success. The literature review occurred in three stages: collection, presentation for feedback, and refinement (Fig. 2). The collection stage was initiated by an internet-based search for keywords, such as “product design” and “eco-design” in combination with keywords related to the academic fields, such as “behavioral psychology” and “environmental psychology.” A list of over 100 relevant references was composed as a starting point. From this list, citations were searched both forward-looking and backward-looking using citation trees within the ISI Web of Knowledge. Simultaneous to the online reference search, experts in the related fields were contacted to confirm the approach and collect additional references. The quickly-growing list of articles was then organized in two categories: type of information (e.g., related observation of interest to designers, design recommendation, design example, “what not to do,” etc.) and cognitive concepts presented in the following. The second stage (review process from peers) relied on the feedback from designers in academia and industry, as well as the experience of the authors. The beta-version of the material featured in this article was presented in large-format talks to research and development groups at the Ford Motor Company, 3M, John Deere (Deere & Company), and Whirlpool Corporation, followed by small group feedback and discussion meetings. It was also presented to academic product design research audiences at the 2012 American Society of Mechanical Engineers Design Theory and Methodology conference and the 2011 INFORMS Annual Meeting on Operations Research in the Green Innovation and Product Development section. Recommendations from these interactions are incorporated in the manuscript in the refinement stage.

1.2. Types of pro-environmental behavior (PEB)

Lofthouse et al. (1999) saw eco-design not only as a technical issue regarding how to engineer a product, but also a focus on product design interaction: how consumers use a product. Three general categories of PEB are useful when conceptualizing the user interaction with an eco-product: curtailing, efficiency, and political behavior. Diminishing use of electricity by turning off lights when not in use is a curtailing behavior (using less through behavior modification); reducing the need for electricity by installing compact fluorescent light bulbs (CFLs) is an efficiency behavior (using less through product modification); changing the source of electricity by voting and campaigning for clean energy is a political behavior. Curtailing, efficiency, and political behavior are influencing and overlapping each other in Fig. 3. Stern (2000) uses four categories: committed environmental activism (dedicated to PEB from all aspects actively), public-sphere environmentalism (accept or support public environmental policies), private-sphere environmentalism (practice PEB personally), and others. We divide private-sphere environmentalism into curtailing and efficiency behavior, those that are most commonly affected by product design. Committed environmental activism represents a synergy of political, curtailing, and efficiency behavior. For a different classification system, see (Renström et al., 2013), where PEB are categorized into five pathways: changed use, mediated use, regulated artifact, maintenance and repair, and choice of artifact. People acting on their environmental concerns often display preferences in one kind of PEB to another, which correlate with demographic information as reported in Barr et al. (2005). The discussion hereafter is tailored to encourage efficiency behavior through the design of eco-products. However, some of the concepts are applicable to all three categories of PEB.

2. The seven cognitive concepts

Seven cognitive concepts that influence PEB are particularly relevant to improving the design of eco-products. These concepts are: responsibility, complex decision-making skills, decision heuristics, the altruism-sacrifice link, trust, cognitive dissonance/guilt, and motivation, as presented in Fig. 4. This section provides explanations and examples of these cognitive concepts, with recommendations for designers. We chose examples that are familiar to engineers, particularly U.S. engineers, in any field. Because of the significant influence of public policy on engineering design decisions (Whitefoot, 2011), some recommendations also involve coordination with policy makers. The concepts are presented in an order that allows the logical flow of conclusions and recommendations in the discussion; this order is not meant to suggest a temporal or hierarchical relationship between the concepts. Examples and recommendation source are summarized in Table 1. The recommendation source is classified by its field of research: Design Research (DR), Technology Research (TR), Business Research (BR), Social Science Research (SR), and Research from Other Fields (OR).

2.1. Responsibility

The sense of responsibility for current environmental problems can be separated into two parts: a sense of responsibility for causing the problems, and a sense of responsibility for solving the problems. The former, when felt as blame and/or guilt, can potentially decrease PEB, as will be discussed in Section 2.6. The latter, when properly guided, may increase PEB.

The environmental “tragedy of the commons” is famously addressed in a parable by Hardin in Science (Hardin, 1968). There is a common pasture that will deteriorate to uselessness if sheep herders only act in their own short-term best interest. Both in this parable and in the real world of communal resource sharing, it is typically a community action that maintains communal resources, rather than individual ones (De Young, 1999). The environmental tragedy of the commons has been remarkably individualized. The individualization began in the 1960s, when naturalists popularized the environmental movement in books such as Silent Spring (Carson...
et al., 1962). These books used generalizations and shock value, a “shame and blame” strategy, to make readers feel an individual sense of responsibility for environmental problems. The environmental movement was later commoditized (e.g., buy a “save the planet” T-shirt) during the individualistic 1980s (Maniates et al., 2002). The 1990s brought the publishing of best-selling books such as Green Consumer Guide (Elkington et al., 1990; Madge, 1997). In Al Gore’s An Inconvenient Truth book (Gore, 2006), out of thirty-four recommendations for “what you personally can do to solve the climate crisis,” only four were community or politically-focused, and they were listed last.

This duality allows individuals to push the responsibility to the “commons” and avoid difficult personal pro-environmental decisions. The intersection of public policy and personal responsibility causes confusion in resolve: people are concerned enough about the environment to desire government to do something about it, but they themselves would prefer to make only voluntary changes as a result of this public policy (Guber, 2003). Individuals can conveniently listen to the messages of hard-core environmentalists who undermine a sense of individual responsibility for the problem, viewing individual PEB as ineffective (Maniates et al., 2002). The majority of U.S. citizens assume that industry and government are already taking responsibility for environmental problems (Guber, 2003). This avoidance is unfortunate, because individual responsibility and PEB are necessary to initiate wide-scale policy changes efficiently and effectively. It is also unfortunate because an individual’s judgment of the extent to which they can personally prevent environmental destruction is a significant indication of their likelihood to purchase eco-goods (Roberts, 1996). People feel they do not have individual control over solving environmental problems (Allen and Ferrand, 1999; Van Birgelen et al., 2009). Recommendation 1 details how design strategies help enhance individual responsibility.

**Recommendation 1:** Instill a sense of personal control over the solution, not responsibility for causing the problem, by designing products with interactive curtailing features. When eco-products offer features that not only increase efficiency behavior, but also offer opportunities to perform curtailing behavior on an elective and repetitive basis, customers will have multiple options to expressing individual PEB. The ideal design would include waste-reduction features that the user interacts with on a regular basis and feels a small reward for performing; thereby feeling empowered to become part of the environmental problem solution.

A simple example of a curtailing design modification is select-a-size paper towels (Fig. 5); more perforations on paper towels at smaller intervals offer a choice to tear off a smaller piece of towel for smaller-sized jobs. An energy saving mode on a printer (Fig. 6) lets customers lower their environmental impact by curtailing their

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**Fig. 4.** Eco-design recommendations derived from the seven cognitive concepts.
energy use. The towel/printer can be sustainably designed, providing an efficiency behavior, and also offer the customer the opportunity to perform a curtailing behavior.

A recent marketing study (Sheth et al., 2011) implies that careful design might trigger a mindset of caring for self, community, and nature, and thus have potential influence on advancing PEB. Specifically, a product can be designed with attributes that help reduce repetitive consumption, such as those being made easier to upgrade or repair, affording use by multiple users, or with attributes that foster responsible consumption, such as providing an option to save energy, and enable built-in educational feedback.

Table 1
A summary of cognitive principles, recommendations, related examples and supporting evidence.

<table>
<thead>
<tr>
<th>Cognitive concepts</th>
<th>Recommendations</th>
<th>Examples</th>
<th>Recommendation source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Responsibility</td>
<td>1. Instill a sense of personal control of the solution by designing products with interactive curtailing features</td>
<td>Good example: Energy saving mode on a printer Better example: Select-a-size paper towels Best example: Shower head fingertip shut-off for shampooing</td>
<td>(Roberts, 1996)SR, (Tolenko et al., 2008)DR</td>
</tr>
<tr>
<td>Complex Decision-making Skills</td>
<td>2. Constrain customers’ product decisions with industry standards</td>
<td>Energy Star program</td>
<td>(Levin, 1993)SR, (Maniates et al., 2002)SR</td>
</tr>
<tr>
<td></td>
<td>3. Encourage tackling of complex decisions through interaction incentives and designed-in educational feedback</td>
<td>Chevrolet Volt panel encourages drivers to achieve higher MPGs Real-time feedback on home electronics increases energy savings</td>
<td>(Ehrhardt-Martinez et al., 2010)TR,SR, (Midden et al., 2007)SR</td>
</tr>
<tr>
<td>Decision Heuristics</td>
<td>4. Address the customers’ environmental concerns as well as the crucial environmental issues</td>
<td>Green Mountain biodegradable or reusable K-Cups Example of what not to do: Mercury in CFLs</td>
<td>(Slimak and Dietz, 2006)SR, (Guber, 2003)SR</td>
</tr>
<tr>
<td></td>
<td>5. Identify useful heuristics and use them to educate about the product’s environmental impact</td>
<td>1 CFL — 10 incandescent light bulbs Heuristics are needed to help users quantify the dosage of laundry detergent to use</td>
<td>(Winter, 2000)SR, (Sandahl et al., 2006)TR, (Jarvi and Palovito, 2007)SR</td>
</tr>
<tr>
<td></td>
<td>6. Identify perceptual product cues that communicate environmental impact</td>
<td>Vitra Vegetal chair looks like tree branches</td>
<td>(Reid et al., 2009)DR, (She and MacDonald, 2014)SR</td>
</tr>
<tr>
<td>Altruism-Sacrifice Link</td>
<td>7. Offer only “triunphs” and downplay altruism in the product’s design</td>
<td>Bamboo resin flooring is marketed as modern Cold-water detergent emphasizes money savings</td>
<td>(Van Birgelen et al., 2009)SR, (Sandahl et al., 2006)TR</td>
</tr>
<tr>
<td></td>
<td>8. Apply design for upgradability or adaptability to work-horse products that are known for reliability and are not status symbols</td>
<td>Office Equipment/Copy machines can be upgraded with additional features</td>
<td></td>
</tr>
<tr>
<td>Trust</td>
<td>9. Design trust into the product’s form using semantics and heuristics</td>
<td>Vitra Panton chair uses lines of traditional chair to communicate sturdiness</td>
<td>(Wang and Emurian, 2005)TR</td>
</tr>
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<td></td>
<td>10. Design trust into the product’s interactions using similarity</td>
<td>Bank web site resembles the visitors’ cognitive styles leading to increased trust</td>
<td>(Hauser et al., 2009)SR, (Urban et al., 2009)SR</td>
</tr>
<tr>
<td>Motivation</td>
<td>12. Change PEB motivation from extrinsic to intrinsic with small, well-timed incentives designed into product interactions</td>
<td>Honda Insight gas tank is smaller to emphasize money saved Baby bird litterbin delights people as they throw their trash away</td>
<td>(Guber, 2003)SR, (Geller et al., 2002)SR</td>
</tr>
<tr>
<td></td>
<td>15. Design product with social norms in mind</td>
<td>Compare electricity usage amongst neighbors Hygienic automated faucets also conserve water</td>
<td>(Nolan et al., 2008)SR, (Braverman, 2010)SR</td>
</tr>
</tbody>
</table>

* Recommendation Source: Social Science Research (SR), Design Research (DR), Technology Research (TR).
2.2. Complex decision-making skills

The average American citizen has limited understanding of environmental problems and risks (Koehn, 2006; Sterman, 2008) and of the tools engineers use to convey relevant information, including eco-labels and life cycle analyses (D’Souza, 2004; Erskine and Collins, 1997). The “Reasonable Person Model” suggested by Kaplan (2000) asserts that the sensation of being overwhelmed by complexity is a central problem in environmental decisions. It asserts that, because of the way humans evolved, we gravitate towards situations where we are capable of processing information, and avoid situations which challenge this capability. Levin (1993) found that too much environmental information led to anxiety and confusion. The research agrees with other findings on cognitive complexity, such as the rule of seven (Miller, 1956) and discussions of simplicity (Maeda, 2006). Simplifying environmental-related decisions and equipping people with the tools required to address them, such as education, are beneficial for promoting PEB, as will be addressed in Recommendations 2 and 3.

Recommendation 2: Constrain customers’ product decisions with industry standards or regulations. Product-category-wide environmental impact constraints remove some complexity of the individual customer’s product decision. The Energy Star program is a good example of such a standard that has helped customers to simplify product decisions (Energy Star Program, 2013). This follows the commons/individual duality, in that people are willing to make choices that are environmentally beneficial, but that they prefer if these choices be constrained through political action (Maniates et al., 2002). However, an industry-wide standard, such as Energy Star, will not help differentiate products if all available products comply, unless the standard is of a graduated type such as the-less-the-better.

Recommendation 3: Encourage tackling of complex decisions through interaction incentives and educational feedback. Incentives can be provided to motivate an individual to tackle a complex decision. Designing small incentives into a product to increase motivation to perform PEB is discussed in Section 2.7. In addition, monetary incentives may encourage potential customers to increase the complexity of their usual product purchase decision to include environmental considerations.

Real-time feedback on resources consumed by a product during use is such a type of interaction, and it can be designed as a customer reward. A comprehensive review of residential sector feedback studies on household electricity use suggests that real-time feedback generates at least 9% energy savings per household in the past decades (Ehrhardt-Martinez et al., 2010). This feedback can help the customer to understand the impact of small behavior changes and implications of specific end uses and thus promote PEB. The feedback also can improve the user’s trust of the product claims, increase their motivation to continue performing PEBs, and strengthen their sense of responsibility and resolve for performing PEBs (Fogg, 2003; Midden et al., 2007). Wilson et al. (2013) designed an electronic sensor device that uses light and sound feedback to discourage the waste of household radiator heat, using input from user focus groups. The work offers a useful and detailed set of evaluation questions associated with the design process. A good example of rewarding incentives combined with feedback is found in the Chevrolet Volt dashboard display, which makes fuel savings a game via a balancing-ball interface, shown in Fig. 8. The ball communicates the complexities of driving efficiently in a fun and non-intrusive manner. During driving, the Volt encourages drivers to beat their previous efficiencies and provides a small incentive in the form of a feeling of reward, indicating decreases in miles-per-gallon-equivalent.

2.3. Decision heuristics

Decision heuristics are “shortcuts” that exist in one’s mind in order to simplify judgments and decisions (Tversky and Kahneman, 1974). They are simple, general, efficient rules that develop through experiences, and are hard-coded via evolution. Heuristics help people make “fast and frugal” decisions (Gigerenzer et al., 2004) and usually lead to good decision outcomes, but they can also lead to irrational and/or erroneous judgments and decisions.

For environmental impact, heuristics are not well-calibrated. Several established heuristics have negative implications for eco-product purchase decisions. For example, consider the popularity of bottled water because it is “healthier” rather than addressing the larger problem related to the waste created by the bottles. The
public's concern for specific environmental threats is not aligned with their actual risk (Slimak and Dietz, 2006). One explanation is the availability bias and heuristic: people assess the likelihood of the occurrence of a given event based on the ease of recollection of similar events. Oil spills, nuclear plant accidents, and poisoned drinking water have received much media attention over the past two decades. This attention makes these environmental disasters easier to recall. Thus, people assess the resultant threat to the environment as more likely and possibly more severe than less-exposed environmental problems. Guber reports that poll respondents are much more likely to be worried about air and water pollution—perceptible forms of pollution—than about global warming, ozone depletion, and deforestation (Guber, 2003). Logging companies specifically keep strips of trees intact next to highways (Winter, 2000), in order to prevent travelers from using the availability heuristic to judge the level and impact of deforestation.

The affect heuristic causes a person to judge the likelihood of a specific decision outcome based on the explanation of the outcome—a positively-described outcome is assigned a higher likelihood of occurring than a negative one (Slovic et al., 2004). Much information on eco-products is framed negatively, in terms of the product's degrading effects on the environment (e.g., carbon footprint of a product), and therefore people may think that purchasing a product's degrading effects on the environment (e.g., carbon footprint of a product) will be questioned. An excellent example of this problem is carbon fluorescent light bulbs (CFL). All CFLs contain a small amount of mercury. When a CFL breaks, the mercury is released. Triggered by the availability heuristic, people consider the environmental and health concerns associated with mercury and conclude that CFLs cannot be as good for the environment as they claim. The Environmental Protection Agency (EPA) has a website devoted to debunking this myth (Environmental Protection Agency, 2011), explaining that the real concern with mercury is when it is released by the burning of coal in power plants. However, educational discussion is not enough to counteract the strong availability effect. Wider spread implementation of CFLs could be achieved by addressing customers' fear of mercury by either excluding it altogether or including a containment mechanism if the bulb happens to break. Considerations of both environmental concerns and customer perceptions are critical to successful eco-product design. Designers should coordinate complex trade-offs by design, rather than assume that education can retrain previously formed heuristics.

Another example is the single-serve coffee market, made popular by the K-Cups offered by Green Mountain coffee and the Keurig line of related coffee-makers. There are environmental advantages to this approach to coffee brewing, such as the reduced use of electricity (do not need to keep a pot of coffee warm all day, brew only what will be consumed), but the waste created is noticeable. Realizing that their customers care about the waste created by using single-serving coffee cartridges, Green Mountain is working to use more biodegradable packaging, recycle the cartridges, or make them reusable (Carpenter, 2010).

**Recommendation 5: Identify useful heuristics and use them to educate about the product's environmental impact.** The
energy-saving aspects of CFLs were most effectively communicated in American marketing campaigns when the energy usage was compared directly to the \textit{status quo}, incandescent bulbs (1 CLF = 10 incandescent, CFL bulbs last about 10 times longer than incandescent bulbs) (Sandahl et al., 2006). The EPA website mentioned above uses a similar approach to put the mercury threat into perspective (Environmental Protection Agency, 2011): “On average, CFLs contain about four milligrams of mercury sealed within the glass tubing. By comparison, older thermometers contain about 500 mg of mercury — an amount equal to the mercury in over 100 CFLs.” Similarly, an effective home energy audit describes the energy lost through poor insulation as “the equivalent of a hole the size of a football in your living room” (Winter, 2000).

For some products, use phase is an important component of overall life-cycle impact, and proper use requires educating the consumer. A study of laundry detergent impact (Jarvi and Paloviita, 2007) showed that customers have difficulty calculating and measuring the correct amount of detergent for their laundry based on criteria such as water hardness, and liquid volume metrics (such as 42 mL). The results of this study indicated that providing effective education heuristics is helpful for changing use phase impact. 

\textbf{Recommendation 6: Identify and use perceptual product cues that communicate environmental impact.} Environmental impact can be expressed through the way the product is perceived. For example, the form of the Vegetal chair by Vitra emphasizes Vitra’s commitment to eco-friendliness with a branch-like design, as shown in Fig. 9. Its plant-like structure evokes nature and environmental concern (Vitra, 2011). Once a person has made a decision to purchase an eco-product, they will be more observant of perceptual information that confirms their decision, and less observant of information that goes against their decision, an artifact of confirmation bias (Mynatt et al., 1977). This bias serves to reinforce pro-environmental cues in products and is one explanation for the fact that the Prius’ silhouette is now identified with “environmental friendliness” (Reid et al., 2009).

Creating designs that communicate lower environmental impacts requires the development of new research methods. Related fields of study include emotional design (MacDonald et al., 2009b; Norman, 1998), product semantics (Krippendorff, 2006), and are covered in books such as Norman’s \textit{The Design of Everyday Things} (Norman, 1998). MacDonald has previously identified the crux/sentinel (i.e., hidden/perceivable) product attribute relationship (MacDonald et al., 2009a). The related design method presented can be used to identify other product attribute relationships, such as eco-product cues.

One design approach creates features that trigger consumers to think about the environment in their product decisions (She and MacDonald, 2014). These “superficial” visible features encouraged customers to seek more information on a product’s environmental impact (She and MacDonald, 2013). Forthcoming results further indicate that these features cause customers to change their purchases in favor of products with lower environmental impacts (She, 2013). Engineering design methods that identify preferences and sentiments associated with a product’s form (Kelly and Papalambros, 2007; Orsborn et al., 2009; Reid et al., 2009) can be modified to identify product forms that communicate lower environmental impact. Also, shape-search design methods (i.e., Iyer et al., 2005) can be modified to search existing design forms to identify forms associated with lower environmental impact.

2.4. Altruism-sacrifice link

Researchers have found a relationship between willingness-to-pay for sustainability and altruism (Stern et al., 1993). Altruism is associated with an implicit message of self-sacrifice for the sake of others. Kaplan (2000) postulates that “[t]he focus on altruism [in PEB] brings with it the implicit message that living with less will result in an impoverished and joyless future,” and wonders how an eco-product purchase can be seen to serve both a self-interested and an altruistic purpose. Some people perceive a link, a heuristic, between higher levels of consumption and greater happiness (Geller et al., 2002). An eco-product reduces consumption: people may believe this implies a reduction in product performance. It has been shown that customers are unwilling to make sacrifices with regard to crucial performance metrics of the product in order to improve sustainability (Van Birgelen et al., 2009). Early products advertised as eco-friendly or green did offer inferior performance at increased prices, only strengthening this unfortunate heuristic. For example early CFL light bulbs were only a niche residential product until their design specifications regarding light color and quality approached or exceeded those of incandescent light bulbs (Martinot and Borg, 1998; Menanteau and Lefebvre, 2000). One of the lessons learned from the American CFL programs was to delay launching products rather than ask customers to sacrifice on core design requirements, as first impressions become strong heuristics and are difficult to overcome (Sandahl et al., 2006). Additional benefits of the bulbs, such as reduced heat and fire hazard, are now highlighted in educational and marketing campaigns. Modern eco-products must overcome the stigma created by their predecessors by consistently offering as-good or better performance than the competition. Another example, Norwood and Lusk (2011) found that, on average, people are willing to pay $0.55 extra for cage-free eggs in US. But in reality, cage-free eggs are typically sold at a premium of $1.50 or more, requiring a budget sacrifice that outweighs concerns for the hens’ welfare, thus leading to poor sales. It indicates that even though customers care about the impact of their behavior, large sacrifices in personal benefit hinder good intentions.

\textbf{Recommendation 7: Offer only “triumphs” and downplay altruism in the product’s design.} Use extreme caution when including a message of altruism in the product’s design or marketing campaign, as the customer could infer that the product is inferior to the competition. Including luxurious finishes or indulgent design features (while minding product perception) may negate feelings of altruism and sacrifice associated with buying an eco-product. An example of an eco-product that has transcended the altruism-sacrifice heuristic is bamboo resin flooring. The flooring has been positioned in the market as modern, durable, and affordable. One brand, Eco-timber, was rated the best in the category of prefinished floors, against standards such as oak and maple (Anonymous, 2009). The pro-environmental features (VOC-free non-toxic adhesive and renewable bamboo resources) are positioned as bonuses, second to the price, durability, and modern appearance. When customers have the feeling of performance
sacrifice for “green” products, it is necessary to downplay this attribute in the product’s packaging. Coldwater laundry detergents, which can reduce energy use by three-quarters (Martin and Rosenthal, 2011), was a hard sell for several years. Manufacturers increases its sell by downplaying altruism-sacrifice link, e.g., relegate energy saving as attendant benefits, and emphasize other attributes (Martin and Rosenthal, 2011). This effort is also evident in Tide’s detergent bottle. Fig. 10 shows an old Tide Coldwater detergent bottle (on the left) and a current bottle (on the right).

An eco-product should create demand through design benefits to the customer— it should be a triumph, offering performance equal to or better than competing products and extra features. Some eco-design tools try to consider environmental as well as traditional quality requirements, such as House of Ecology (Halog, 2001), Quality Function Deployment for Environment (Masui et al., 2003) and Function Impact Matrix (Bernstein et al., 2010; Devanathan et al., 2010). They confirm that environmental improvements can be made without affecting functional performance. Fitzgerald et al. (2010) offer a conceptual design tool that helps designers to resolve functionality-environmental contradictions in the product design, and provide products that are desired by customers and also excel from an environmental standpoint.

**Recommendation 8:** Apply design for upgradability or adaptability to work-horse products that are known for reliability and are not status symbols. Adopting End of Life strategies, such as remanufacturing and upgradability, to recover the value of a used product is an effective and promising eco-design method. It is suggested that constraints imposed by these strategies should be integrated into the early phases of design (Gehin et al., 2008). There are a number of eco-design methods that allow products to be upgraded or adapted to include new features, such as design for upgradability (Xing and Belusko, 2008) and design for adaptability (Kasarda et al., 2007). Xerox makes upgradable office equipment, such as allowing lower version digital copiers to upgrade to a fully networked system. Copiers are an excellent example of a winning upgradability approach — it is a product category where customers are looking to save money and maximize the useful lifetime of a single product purchase. However, products that are associated with status, such as cell phones or automobiles, and brands with negative reliability stereotypes, such as some printer and automobile brands, must proceed with caution in refurbishment or reuse design strategies.

### 2.5. Trust

To navigate the above cognitive concepts while actively searching for an eco-product, the consumer has to overcome a number of trust issues. For example, a person must trust (a) the science that identifies the environmental problems, (b) his or her ability to personally affect the problems with PEB; (c) the pro-environmental claims made by the product; and (d) the up-to-par performance of the product. It may seem reasonable for a person to seek expert advice to aid their search; however, experts from the environmental movement are not fully trusted by the public. In her analysis of the results of a number of polls, Guber (2003) came to the conclusion that “[b]y downplaying environmental progress and using exaggerated doomsday warnings to motivate public awareness and concern, the environmental movement has sacrificed its own credibility by giving into the politics of Chicken Little.”

Eco-labels and environmental marketing messages are also often not trusted by customers (D’Souza, 2004; Lampe and Gazda, 1995; Shrum et al., 1995). Eco-labels on products or product packaging are a form of “direct persuasion” advertising, with information provided by the products’ manufacturer. Direct persuasion advertising may also shift responsibility for the behavior, leading customers to think that ultimate blame for consequences of their environmental decisions rests on another party, namely the persuader (Geller et al., 2002). This is not to say that all eco-labels are useless and do more harm than good, but it is important for designers to note that eco-labels may have drawbacks and are ineffective as the sole conveyers of a product’s environmental impact.

It is often difficult for customers, and other stakeholders, to ascertain the extent to which a firm’s products and processes are sustainable. The firm may have an incentive to deceive in marketing messages, otherwise known as “green washing”, if they wish to appear more committed to sustainable practices than they actually are. Therefore, costly mechanisms such as ISO 14000 certification (International Organization for Standardization, 2013) and investment in eco-technologies are all examples of signals that can communicate a commitment to sustainability to various stakeholders (Connelly et al., 2011). For example, considerable investment in a grass roof for a manufacturing plant may make more sense than an eco-labeling program as it is highly observable and costly to imitate (Connelly et al., 2011). Green Mountain Coffee installed a “huge solar array on the roof of its distribution center” in 2009 (Carpenter, 2010).

**Recommendation 9:** Design trust into the product’s form using semantics and heuristics. Industrial designers have been taught to evoke trust in an object’s form. They utilize the theory and analysis of design semantics (Krippendorff, 2006) to create a perceptible sense of trust in the visual lines of the product. Establishing “trustworthy” heuristics, for example using the above-mentioned crux/sentinel attribute identification method (MacDonald et al., 2009a), will help customers identify eco-products and reinforce their decision-making approach such that specific forms will become heuristics in future product purchases. The Vitra Panton chair (Fig. 11) distributes load and stress through one single cohesive form. Although the form is unusual, the robust cantilever base reassures customers that they will not tip over. The strong silhouette of the side of a chair also evokes trust through the recognizable chair-shape. Wang and Emurian (Wang and Emurian, 2005) discuss fourteen trust-inducing interface design features that may influence a user’s perception of the trustworthiness of an online merchant’s web site. These features are highly correlated with the heuristics people often use to judge credibility, such as well-chosen, professional photographs and relevant domain names; however, extending this approach to product design will require more research.

**Recommendation 10:** Design trust into the product’s interactions using similarity. If a product has a computer interface, a
number of studies suggest that the product is considered more trustworthy and persuasive if the interface resembles the user (Fogg, 2003). “Resembles” can refer to the cognitive style in which the information is presented, i.e., visual or verbal (Hauser et al., 2009), or other personality traits, physical traits, or affiliations that resemble the customer (Fogg, 2003). Urban et al. (2009) studied websites selling credit card loans and showed that people are more likely to trust a website when it resembles the visitors’ cognitive style (analytical vs. impulsive, for example). With further research it may be possible to use these findings for product design. Cognitive-style dimensions related to design could include, for example, flexible vs. inflexible, innovator vs. traditionalist.

2.6. Cognitive dissonance and guilt

When an individual performs a behavior with the intent of reducing environmental impact, but later realizes that the behavior is detrimental to the environment, they will experience cognitive dissonance, a mismatch between cognition and action, or value and behavior. They will have a strong need to resolve the mismatch (Festinger and Carlsmith, 1959). Changing behavior to match their values resolves the dissonance, so triggering cognitive dissonance can motivate the performance of PEB. However, people can also resolve cognitive dissonance by changing cognition to match behavior (Immerwahr, 1999; Vining et al., 2002). People can change their values, attitudes, or beliefs about the environment to a position of less concern. Note that resolving cognitive dissonance in this manner for one behavior will affect all other behavior—the person may fundamentally decrease the importance they place on environmental problems, or their belief that environmental problems exist. A customer may change their decisions about the eco-products they currently buy. Therefore, attempting to motivate PEB by intentionally triggering cognitive dissonance is not advised.

People can experience feelings of guilt about negative environmental impacts if they have formed an individualized sense of responsibility, listened to the “shame and blame” tactics of the early environmental movement, or experienced unresolved cognitive dissonance regarding the products they buy. In motivating PEB, researchers stressed that inducing feelings of guilt should be avoided, as guilt can cause a change in behavior, but it can also cause a disguise or denial of the target behavior (Levin, 1993).

Recommandation 11: Avoid making customers feel guilty. Be cautious of product interactions that trigger guilt or cognitive dissonance. Work with marketers to remove these concepts from marketing campaigns. Before introducing a new eco-product, it is important to study the customers’ impressions of the environmental impact of current product offerings. If customers believe that the available products are conscientious of environmental concerns, introducing a new eco-product by the same company may cause cognitive dissonance regarding the product they currently purchase. The designer/business can avoid this situation by positioning the two products so they are not directly compared, using features, pricing, and branding.

At a recent eco-design workshop, an electronics company displayed a prototype interface for monitoring home electricity usage that showed a penguin on an iceberg. The iceberg melted and eventually disappeared if the homeowner used too much electricity. This type of interface should be avoided because it will trigger guilt and may result in customers changing their level of concern for the environment. Monitoring interfaces should highlight accomplishments, not shortcomings. This is consistent with Lilley’s (2009) recommendation for the design of eco-devices. Lilley explored the design strategies for changing mobile phone users’ behavior in public spaces and investigated the acceptability and effectiveness of potential strategies with design professionals. The interviewed design professionals agreed that “in order to be accepted, the product would need to support, not contradict, user’s values”. This led to her recommendation to “Use predominately positive, rather than negative reinforcements” when trying to change user behavior (Lilley, 2009). Flora discusses behavior change in general, not just related to environmental concerns, and concludes that positive reinforcement is more effective than criticism overall (Flora, 2000). Praising PEB will better facilitate learning and positive motivation than criticism of behavior that has damaging environmental impacts (Geller et al., 2002). A mobile phone application developed by Froehlich (2011) motivates users to make greener transportation choices (e.g., walk, bicycle, carpool) by using a tree design. The tree is almost bare at the start of each week, then leaves, blossoms, and apples are progressively added to the tree after each use of green transportation. But the tree does not lose growth when a car is driven, instead it only resets each week. The tree growth rewards greener behavior, and the positive-only growth sequence avoids making users feel guilty.

2.7. Motivation

Applied behavior analysis is a sub-field of psychology that researches how to motivate change in behavior. Vining et al. (2002) review the three types of behavior motivation: (1) intrinsic motivation, in which a person derives satisfaction from performing the behavior; (2) extrinsic motivation, in which person derives satisfaction from a reward given when the behavior is performed; and (3) a motivation, in which a person receives no satisfaction from the behavior, and is unsure why they are performing the behavior. One would expect that a personal norm or feeling of moral obligation provides a strong intrinsic motivation for PEB, but this is not always the case (Tanner and Wolfling Kast, 2003). People are most likely to participate in PEB through extrinsic motivation: when there is a tangible incentive and personal sacrifice is minimal (Guber, 2003). Financial incentives as well as guilt and/or cognitive dissonance are examples of extrinsic motivators—correcting behavior gives the reward of the removal of an unpleasant cognitive state, but as discussed, they can lead to unwanted consequences.

Applied behavior analysis shows that PEB can be promoted by specific extrinsic motivators that must be tailored to the desired behavior change. Eco-product purchase decisions are best motivated by incentives that are short-term, repetitive, and small in size: “[r]eward schedules that are just sufficient to initiate behavior change are more likely to produce longer-term behavior change than more powerful rewards” (Geller et al., 2002). This can be explained by the fact that people attribute the reason for behavioral change to the relevant circumstances and the size of the reward. A large, one-time incentive to motivate PEB causes a person to attribute the change to the efforts of the one providing the incentive. Small, repetitive incentives cause a person to eventually attribute the change to their own volition, thus shifting from extrinsic to intrinsically-motivated PEB (Geller et al., 2002). This transition is important to achieving repeat eco-product purchases and effective use.

Recommendation 12: Change PEB motivation from extrinsic to intrinsic with small, well-timed incentives designed into product interactions. Eco-products that aim at long-term reduction of environmental impacts can be designed to include features that provide near-term benefits, such as including fair trade or locally-produced materials (Tanner and Wolfling Kast, 2003). Delight in product features can also be considered a short-term incentive. Features that can provide such incentives can be investigated by design methods that discover delighting product attributes (Kano et al., 1984; MacDonald et al., 2006). The proper
spacing of incentives to achieve the transition from extrinsic to intrinsic motivation requires design creativity. Next paragraph shows some examples.

Smaller and more fuel-efficient hybrid cars, such as the Honda Insight, are fitted with smaller gas tanks. Because of the car's high mile per gallon (MPG) capacity, the driver may fill the tank as often as with a conventional car, but he will buy less gasoline. Needing to pay less for gas and driving the same distance will convey a feeling of delight, an incentive that is received every time the tank is filled. If Honda had designed the Insight with a tank similar in size to non-hybrid cars, would have allowed customers to drive further between fill-ups instead of cheaper fill-ups. In this case, the driver would not receive the same repeated feeling of delight. It is likely the customer would not notice the change in fill-up frequency as vividly as the change in the cost per tank of gas, and would not feel the same sense of reward. A nightclub in Netherlands uses a new type of dance floor that harvests the energy generated by jumps and gyrations and transforms it into electricity to supply the energy required for the whole club. The dance floor, which functions through piezoelectricity technology, motivates customers' PEB by providing enjoyment (Rosenthal, 2010). The open beak of a “baby bird” litterbin encourages children to feed the hungry bird by putting the garbage into its beak, rewarding them with a feeling of delight with each use (Lockton et al., 2010b).

**Recommendation 13: Work with policy makers and marketers to design thoughtfully-structured eco-product purchase incentives.** An example of a good incentive for transitioning from extrinsically to intrinsically motivated PEB is California’s “Clean Air Sticker” program (California Department of Motor Vehicles, 2013). California issued 85,000 clean air stickers to hybrid and low-emission vehicles that allowed the driver to use carpool lanes with only one passenger in the vehicle. Every time the owner drives the vehicle, they receive a small incentive in the form of a faster commute time and savings of $2.00 to $4.00 when using a toll road. The vehicles with stickers also retained a higher resale value. A large, one-time financial incentive in the form of a rebate on a new car purchase (i.e., the U.S. “Cash for Clunkers” program) is unlikely to spur future PEB (Wald, 2009). Sloan (2011) examined a variety of potential policies for influencing firms to adopt cleaner manufacturing technologies, drawing examples from the automobile and refrigerator industries.

Public policy has played a crucial role in developing CFLs from a niche lighting product into a mass product in the residential market (Menanteau and Lefebvre, 2000; Sandahl et al., 2006). A variety of incentive and educational programs have been used in different countries to encourage their adoption (Martinot and Borg, 1998). However, no country made the transition to CFLs by passing a law that mandated CFLs for all residential applications. On the other hand, no country made the transition to CFLs by passing the bulbs on the shelves in retail stores and waiting for customers to purchase them based on economic merits alone. Governments and manufacturers introduced CFLs through policies that encouraged their use on an elective basis by individuals. When CFLs are widely adopted, stricter use laws can be instated, such as California’s Title 24 Residential Lighting Building Code that imposes strict efficiency requirements on built-in lighting fixtures (The California Energy Commission, 2008).

Policy-makers benefit from motivating individuals to perform PEB (Jackson, 2005). Eco-technologies are more cost-effective and implemented faster when individuals are willing to accept the technologies or even demand them. The coordination of perspectives is recognized as important—there is now a bill under consideration in the U.S. Senate to add a social and behavioral science office to the Department of Energy (Baird, 2009). The impact of policy on design decisions has been explored in the literature, see (Shiau et al., 2009; Struben and Sterman, 2008).

**Recommendation 14: Design eco-products for ease of use.** The rationale most frequently provided for not performing PEB is that requires effort (Koehn, 2006). One study demonstrated that perceived behavior barriers to transportation (e.g., low frequency of public transport, transfers necessary with public transport) are closely associated with increased automobile driving frequency (Tanner, 1999). At a recent webcast offered by the Department of Energy, Gainesville Regional Utilities (GRU) reported their success of a Home Energy Reporting Program, where simple steps to save energy are always highlighted (Crawford and Fischer, 2011), e.g., weatherization and sealing and using CFL bulbs. These tips are easy to follow and thus prompt people to be more likely engaged in energy-saving activities. Eco-products should be easy to use and understand. Product heuristics, or emotional design, that read as “easy” or “simple” can be built into design features to provide further encouragement. Some examples include: perforations on select-a-size paper towels (Fig. 3), and sophisticated hybrid transmission systems that simplify the process of shifting and sharing power among the engine, electric motors and wheels without requiring special driving techniques. Designing a product to be simple to repair or upgrade is a related goal, especially in products for which early replacement is environmentally desirable (van Nes and Cramer, 2006).

**Recommendation 15: Design product with social norms in mind.** Normative social influence has a powerful effect on behavior, especially in defining what constitutes correct behavior—“We view a behavior as correct in a given situation to the degree that we see others performing it” (Gialdini, 1993). That explains why infomercials always demonstrate people from various walks of life happily buying and using the advertised products. Nolan et al. (2008) studied what motivated people to save energy by placing door-hangers containing different persuasive appeals around a mid-size Californian community. The appeals emphasized to residents that turning off an air conditioner and turning on fan: (1) saves money, (2) helps the environment, (3) benefits society, or (4) is a common practice in their neighborhood (appealing to social norms). Actual energy usage indicated that the social-norms appeal had significantly higher impact on reducing energy consumption (Nolan et al., 2008). Gainesville Regional Utilities (GRU) also employed social norms when comparing residential utility customers' electricity use to that of their neighbors in their innovative home energy reports (Allcott, 2011). One of the 101 strategies for influencing user behavior developed by Lockton et al. (2010b) suggests influencing behavior by showing people what their peers are doing in a similar situation and which choices are most popular, such as Amazon's recommending system. In eco-product design, designers are challenged to take social norms into consideration and encouraged to go out and watch people in their normal environment to determine what they believe and do (Norman, 1999). Automated faucets provide the convenience of hands-free on/off activation and help conserving water. The normative value embedded into the automation, as an automated faucet is also more hygienic, motivates customers to use the product, and repeated use shapes their behavior (Braverman, 2010).

3. **Discussion of implementing recommendations within design methods**

The concepts have implications when used in conjunction with concept-generation design methods that focus on understanding customers. For example, an application of these concepts during conceptual design would work well in conjunction with an empathic design approach (Leonard and Rayport, 1997), as it is
important to feel and experience as the target customer does with respect to the application of the seven concepts. Eco-design paired with a lead user approach (Vonhippel, 1986) may yield dissatisfaction results. Lead users are at the forefront of the market demand, and, for eco-products, lead users are likely to be well-versed in environmental impact evaluation and willing to sacrifice functionality for the benefit of the environment. A better approach might be to target “lag users,” for example, someone particularly frustrated with understanding information about eco-products, or someone who has had negative experiences with eco-products in the past and stopped using them.

Jelsma (2006) provides an eight-step design method to solve discrepancies between designers’ and users’ understanding of a product’s interaction by involving users in the design process. The recommendations provided here can help to identify misunderstandings. Tang (2010) highlights that including detailed user studies, such as ethnographical observations, in the design process can help designers generate innovative design concepts, provide better and more efficient user experience via design, and improve the user acceptance of behavior-changing concepts. The cognitive concept categories presented in this article may offer specific guidelines for what to be sure to address during observation.

Designers need to be careful when implementing design-led approaches to influence user behavior — maintaining a balance between influencing and coercing will allow users to accept the design implementation (Lilley, 2007). As many of the recommendations are geared at influencing behavior, using them in combination may be either more effective, or they may negate each other. A user-oriented design process should be able to identify particular implementations that work well.

Consumption behavior is driven by a complex set of forces originating from different psychological, social, economic, and political settings (Mont and Plepys, 2008); therefore, design for PEB requires a multidisciplinary approach with input from different stakeholders: government, businesses, customers, and non-governmental organizations. Design decision literature offers many methods to address this multi-pronged, multi-perspective design problem (Frischknecht et al., 2009; Lewis et al., 2006; Linton, 2002). The literature recommends a system and interdisciplinary perspective for both addressing and teaching eco-friendliness, and the findings in Anastas and Zimmerman (2003); Harper and Thurston, 2008; McAlloon, 2007) further emphasize the importance of this approach.

4. Conclusion

Compiling diverse research findings from a broad disciplinary scope, we converge on seven cognitive concepts that are important to consider in consumer-driven design. They are useful in bringing different perspectives together in the eco-design process, particularly during early stage design, such as during problem definition and concept generation.

Note that existing research in other fields, such as policy making (Dolan et al., 2012) and social community (McKenzie-Mohr, 2011), indicated that users’ behavior play a key role in sustainability, and identified relevant cognitive variables and guidelines to promote sustainable behavior. Although there is some overlap between the existing work and our work on the high-level cognitive concepts, the extended recommendations presented here are tailored to product design. They are presented in a format widely-accepted in engineering design field, providing general design principles and demonstrating their application with related design methods or design examples.

Lack of direct validation of the recommendations is a limitation for this research. The specific design examples and relevant design methods given should be treated as illustrations of how a designer can approach these concepts, rather than as a test of their efficacy. They bridge the gap between the abstract cognitive concepts and their applications in eco-design, and highlight the need for new design methods that treat customers as dynamic and interactive members of a larger social system rather than as a static source of design criteria. Future eco-design studies must focus on achieving positive change in individuals’ behavior using a combination of approaches. Synthesizing the above recommendations and perspectives requires coordination between designers, manufacturers, marketers, and government policy-makers. The success of eco-products depends on the success of this coordination.

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References

Allcott, H., 2011. Social norms and energy conservation. J. Public Econ. 95 (9–10), 1082–1095.
Bovea, M.D., P


Froehlich, J.E., 2011. Sensing and Feedback of Everyday Activities to Promote Environmental Protection. Universities of Washington, Seattle, WA, PhD.


